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In re
U.S. application of: Koichi FUJIWARA, Osamu TOYAMA and Eiro FUJII
For: METHOD FOR CORRECTING A THREE-DIMENSIONAL SHAPE DATA
U.S. Serial No.: 09/749,624
Filed: December 28, 2000
Group Art Unit: 2673
Examiner: Scott Wallace

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DECLARATION AS TO ACCURACY OF TRANSLATION

I, Yukio KUBO, of
(Name of Translator)

Oriental Chisan Building 12F, 1-26,

Nishinakajima 7-chome, Yodogawa-ku,

Osaka-shi, Osaka 532-0011 Japan
(Business Address of Translator)

hereby declare that:

1. I am well acquainted with both the English language and the Japanese language and am a translator of documents of either of the languages into the other of the languages;

2. I have translated into the English language the original Japanese language Specification of Japanese Patent Application 11-372356, filed in Japan, on December 28, 1999;

3. A copy of my English language translation of the original Japanese language Specification of the Japanese Patent Application 11-372356 is attached to this document; and

Serial No. 09/749,624

4. I hereby certify that, to the best of my knowledge and belief, the English language translation is a true and accurate translation of the original Japanese language Specification of the Japanese Patent Application 11-372356.

I hereby declare that all statements made in this document of my own knowledge are true. I hereby declare that all statements made in this document on information and belief are believed to be true. Furthermore, I hereby declare that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued as a result of the application.

December, 26 2003
Date

Y. Kubo
Signature Yukio KUBO

【PAPER NAME】 Patent Application

【REFERENCE NUMBER】 TL03391

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【IPC】 G06T 15/00

【TITLE OF THE INVENTION】 METHOD FOR CORRECTING A THREE-DIMENSIONAL SHAPE DATA

【NUMBER OF CLAIMS】 4

【INVENTOR】

【ADDRESS】 c/o MINOLTA CO., LTD., Osaka Kokusai Building, 3-13, 2-Chome Azuchi-Machi, Chuo-Ku, Osaka-Shi, Osaka 541-8556 Japan

【NAME】 Koichi FUJIWARA

【INVENTOR】

【ADDRESS】 c/o MINOLTA CO., LTD., Osaka Kokusai Building, 3-13, 2-Chome Azuchi-Machi, Chuo-Ku, Osaka-Shi, Osaka 541-8556 Japan

【NAME】 Osamu TOYAMA

【INVENTOR】

【ADDRESS】 c/o MINOLTA CO., LTD., Osaka Kokusai Building, 3-13, 2-Chome Azuchi-Machi, Chuo-Ku, Osaka-Shi, Osaka 541-8556

Japan

【NAME】 Eiro FUJII

【APPLICANT】

【IDENTIFICATION NUMBER】 000006079

【NAME】 MINOLTA CO., LTD.

【ATTORNEY】

【IDENTIFICATION NUMBER】 100086933

【NAME】 Yukio KUBO

【TELEPHONE NUMBER】 06-6304-1590

【CHARGENABLE FEE】

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[PAPER NAME] Specification

[TITLE OF THE INVENTION] METHOD FOR CORRECTING A THREE-DIMENSIONAL SHAPE DATA

[SCOPE OF CLAIMS]

[CLAIM 1]

A method for correcting three-dimensional shape data by joining a surface to a part of a shape model, the method comprising:

a first step of generating a curved surface model that has an outline corresponding to a portion to be corrected of the shape model, an entire curvature of the curved surface model being defined by a parameter corresponding to one input item;

a second step of displaying an image showing a condition that the curved surface model and the shape model are in register; and

a third step of deforming the curved surface model responding to an operation of changing designation of a parameter value.

[CLAIM 2]

The method according to claim 1, wherein shape data in a periphery of the portion to be corrected in the shape model are used in the first step.

[CLAIM 3]

The method according to claim 1, wherein the parameter represents a mean curvature of the curved surface model.

[CLAIM 4]

A method for correcting three-dimensional shape data by joining a surface to a part of a shape model, the method comprising:

a step of displaying a member used for altering a parameter on a screen; and

a step of generating a curved surface model continuously that has an outline corresponding to a portion to be corrected of the shape model and has a curvature depending on a altered parameter in conjunction with a parameter alteration by the displayed member and of displaying an image showing a condition continuously that the curved surface model and the shape model are in register.

[DETAILED EXPLANATION OF THE PRESENT INVENTION]

【0001】

[TECHNICAL FIELD OF THE PRESENT INVENTION]

The present invention relates to a method for correcting a three-dimensional shape data.

【0002】

[PRIOR ART]

Modeling which utilizes a three-dimensional measuring apparatus is performed. For example, a three-dimensional measuring apparatus, using a light-section method, scans optically an object by projecting and deflecting the slit light and calculates a three-dimensional shape data by applying a principle of a triangular surveying. The circumference of the object is measured, a plurality of obtained three-dimensional shape data are connected together, and the shape model for the object as a whole can be obtained.

【0003】

Because of the measuring condition, such as shape, direction, or lighting, sometimes the three-dimensional shape data cannot obtain perfectly, the lacking of the data is occurs. In this case, the filling of a hole, namely the data correction for filling the lacked portion is performed.

【0004】

In conventional, as a method for filling the data lacked portion, the method of generating a new curved surface by deforming a primitive grid, and connecting the generated surface with the outline of the lacked portion is provided. The unexamined Japanese patent disclosure 11-15994 discloses a computer system which can fine adjusting the curved surface by try and error on monitoring the resultant for preventing the unnatural filling the hole. In this system, by designating at least one point inside the curved surface and target position, the curved surface is modified to be smooth surface including the target position, automatically, and the numerical data representing the change of the shape is displayed. The operator evaluates the modification by the numerical data, if the operator does not satisfied the resultant, then designate newly point inside the curved surface and target position.

【0005】

【PROBLEM TO BE SOLVED BY THE PRESENT INVENTION】

In conventional, there is a problem that the operator must designate a large number of values for adjusting the additive curved surface to the shape model and the data correction operation of the shape model is troublesome. Especially, if the shape model has a complex surface with ups and downs, operator must designate many points, therefore the load of operation was heavy.

【0006】

The object of the present invention is to provide a method and system for adding a required curved surface applied on a portion of the shape model by a simply and easy input operation.

【0007】

【MEANS TO SOLVE THE PROBLEM】

A method according to the invention of claim 1 is a method for correcting three-dimensional shape data by joining a surface to a part of a shape model. The method includes a first step of generating a curved surface model that has an outline corresponding to a portion to be corrected of the shape model, an entire curvature of the curved surface model being defined by a parameter corresponding to one input item, a second step of displaying an image showing a condition that the curved surface model is positioned on the shape model, and a third step of transforming the curved surface model responding to an operation of changing designation of a parameter value.

【0008】

According to the correction method of the invention of claim 2, shape data in a periphery of the portion to be corrected in the shape model are used in the first step.

According to the correction method of the invention of claim 3, the parameter represents a mean curvature of the curved surface model.

【0009】

A correction method according to the invention of claim 4 includes a step of displaying a member used for modifying a parameter on a screen, and a step of generating a curved surface model continuously that has an outline corresponding to a portion to be corrected of the shape model and has a curvature depending on a modified parameter in conjunction with a parameter modification by the

displayed member and of displaying an image showing a condition continuously that the curved surface model is positioned on the shape model.

[0010]

[EMBODIMENT OF THE PRESENT INVENTION]

Fig. 1 is a block diagram showing a configuration of a three-dimensional processing system according to the present invention.

The three-dimensional processing system 1 is a computer system and comprises a bus 10, a CPU (central processing unit) 11, a memory 12, an auxiliary storage device 13, an input/output interface 14, a keyboard 15, a mouse 16, and a display 17.

[0011]

The CPU 11 executes various processes including a data modification according to the present invention. The memory 12 includes a ROM 12a for storing a control program scripted a sequence executed by the CPU 11, and a RAM 12b providing a data storage area and a working area required for the execution of the various processes by the CPU 11. The auxiliary storage device 13 is used for storing a objective data such as a three-dimensional data (shape data), a two-dimensional color image data, and so forth. The input/output interface 14 is used for inputting a objective data from external or for outputting a generated data to external.

[0012]

The keyboard 15 and the mouse 16 are used for inputting various instructions or settings. The display 17 displays images of three-dimensional data and generated surface, and also is used for displaying a processing status, a processed result, and a progressive status. The display 17 can display a plurality of windows by a multi-window system.

[0013]

By using the three-dimensional processing system 1, a required curved surface data can be added to a three-dimensional data which is either inputted from the three-dimensional measuring apparatus (not shown), or generated by the modeling system. This function is suitable for a full-filled process of a lacked portion (hole) of a shape model.

【0014】

Fig. 2 is a schematic diagram of filling process. The exemplary three-dimensional data as an object for correction is a shape model M of the mascot doll. The lacked portion 90 is present in the shape model. Namely, an upper side surface portion of the mascot doll is lacked in Fig. 2. The filling a hole process is a data processing such that a grid likes plane surface m is attached on a lacked portion 90, the plane surface is modified to a appropriate curved surface corresponding to the shape model M, and the curved surface is joined to the outline of the lacked portion. Thus, with the three-dimensional processing system1, an operator (user) can fill the lacked portion with the desired curved surface by a simple and easy operation.

[First operation example]

Fig. 3 is a diagram used for an explanation of a first operation example. Fig. 3(a) shows a form of a dialogue window and Fig. 3(b) shows a changing of an image on a monitor display.

【0015】

An operation sequence of the first example is as follows:

(1) In the modeling mode capable of correcting the shape model M, an operator instructs to execute filling a hole with designation of the area which contains a lacked portion. Thus, the three-dimensional processing system 1 specifies an object of a process by detecting an outline of the lacked portion 90, and displays a dialogue window 71 for querying a parameter value (coefficient (, mentioned later) onto a screen of a display 17.

(2) The operator fixes (designates) a parameter value between a range of 0-1 by dragging a knob 714 of a slider in the dialogue window 71. Then, the operator clicks an "Apply" button 711. The three-dimensional processing system 1 performs a calculation for filling a hole, and displays an image G4 showing a resultant of filling on a monitor area 75 in the screen. This calculation process corresponds to a first step of the present invention and displaying of the resultant corresponds to a second step. The image G4 shows a condition that the curved surface m4 is positioned on the

shape model M. A curvature of the curved surface m4 is defined by the parameter value.

(3) When a sufficient result could not obtain, the operator resets appropriately the parameter value, and clicks the "Apply" button 711, again. The operator repeats this operation until the sufficient shape being obtained. In response to modify the parameter value, the three-dimensional processing system 1 recalculates and displays the resultant, repeatedly. This process corresponds to a third step of the present invention. In the example shown in Fig. 3B, after displaying the image G4, the parameter is modified twice in total, the displayed image is changed from the image G4 to an image G2, and further from the image G2 to an image G3, according to the modification of the parameter. Thus, by increasing the parameter value than that of the curved surface m4, the curved surface m2 having a gentle curve in compared with the surface m4 is applied, and by selecting the parameter value between the surface m4 and the surface m2, the curved surface m3 having a curve gentler than the surface m4 and sharper than the surface m2 is applied.

[0016]

Each of images G2, G3, and G4 is obtained by projecting the shape model located in the virtual space onto the screen. The operator can select display mode such as a shading applied surface model, a wire frame model, and the like.

(4) If the sufficient result is obtained, an "OK" button 712 is clicked. Thus, the filling a hole process is completed. The shape model filled the lacked portion is stored in the auxiliary storage device 13 as the resultant corrected three-dimensional data.

[Second operation example]

Fig. 4 is a diagram used for an explanation of a second operation example. Fig. 4(a) shows a form of a dialogue window and Fig. 4(b) shows a changing of an image on a monitor display.

[0017]

An operation sequence of the second example is as follows:

(1) In the modeling mode, an operator instructs to execute filling a hole with designation of the area which

contains a lacked portion. Thus, the three-dimensional processing system 1 specifies an object of a process by detecting an outline of the lacked portion 90, and calculates for filling process by applying a default value of the parameter (e.g., 0.5). The three-dimensional processing system 1 displays an image G3 showing a resultant of filling process on a monitor area 75 in the screen and displays a dialogue window 72 for querying the good or the bad of a parameter value.

(2) The operator can fixes a parameter value between a range of 0-1 by dragging a knob 724 of a slider in the dialogue window 72. In response to dragging, the calculation for filling a hole is performed by applying the parameter value of the dragged portion, and displays resultant images G1-5 showing on a real time. Thus, only by operating the slider, the shape of filling portion can change freely either to be flat or sharp.

(3) If the sufficient result is obtained, an "OK" button 722 is clicked. Thus, the filling a hole process is completed.

[0018]

With such the second operation, the operation of the filling process can more rapidly proceed than the first operation. However, this operation requires that the process performances of the devices including CPU11 are sufficiently high.

[0019]

Hereinafter the calculation for filling process is described.

Fig. 5 is a diagram for illustrating a data processing for filling of a lacked portion.

As shown in Fig. 5(a), it is considered that an x-y plane along with the lacked portion (hereinafter refers to as a "hole") 90 and z direction perpendicular to the x-y plane is set as attached direction, plane (grid) m which is larger than the hole 90 is corresponded to the hole 90. Moving the grid points inside the hole 90 along with the z direction generates the curved surface. When positioning of the grid points of the plane m, an influence of the position (inclination) of the data periphery of the hole 90 in the shape model M is considered. Therefore, the grid points are calculated to minimize a sum up to second

order differentiation among the interpolation points with boundary condition of data position of a periphery of the hole. Thus, by changing coefficients of terms of the first order differential and a second order differential, the shape of the generated curved surface can be changed, and the filling process according to the intention of the user can be achieved.

[0020]

As shown with a wide frame line in Fig. 5, a bounding box BB is generated on the hole 90. The grid is formed within the bounding box BB and also outside of the bounding box BB the grid is formed by 1 line around it. The number of grid point is automatically calculated from the three-dimensional data periphery of the hole 90. The user can also designate the number of the grid points.

[0021]

It is assumed that the grid points inside the hole (white circle of Fig. 5) are unknown data, calculating the position in the z direction is generating of the curved surface. The grid points exist inside of the bounding box BB and outside of the hole (dark circle ● of Fig. 5) are known data, and those are used as boundary values for connecting the shape model with the curved surface. The grid points outside of the hole 90 on the bounding box BB (dark square ■ of Fig. 5) are boundary value. These boundary values can be obtained from the grid points by projecting to a polygon of the shape model M.

[0022]

These boundary value, known data, and unknown data are two-dimensional array as uy,x, y=0, ... Ny+3, x=0, ... Nx+3 (where, Nx and Ny are the number of the grid points in the x direction and y direction, respectively, inside the bounding box BB). The boundary value and the known data is already obtained. The grid intervals in the x direction and y direction are Hx and Hy, respectively.

[0023]

To obtain unknown data, an energy function is determined and the unknown data can be determined to minimize the energy function.

$$E(u) = S(u) + P(u)$$

where S(u) represents the degree of not smooth, and P(u) represents a lag from restriction condition.

[0024]

S(u) represents with the sum of the first order differentiation and the second order differentiation, and P(u) is not considered.

Therefore:

[0025]

[Expression 1]

$$S(u) = \frac{1}{2}\left\{\gamma \sum_{i}^{Ny+2} \sum_{j}^{Nx+2} [(u_{i,j}^{x})^2 + (u_{i,j}^{y})^2] + (1-\gamma) \sum_{i}^{Ny+2} \sum_{j}^{Nx+2} [(u_{i,j}^{xx})^2 + 2(u_{i,j}^{xy})^2 + (u_{i,j}^{yy})^2]\right\}$$

[0026]

$$P(u) = 0$$

In s(u), if the coefficient γ of the first order differential term is near 1, the influence of the first order differential term becomes remarkable. Therefore, the curvature of the generated curved surface becomes small and flat. In the contrary, if the coefficient γ of the first order differential term is near 0, the influence of the second order differential term becomes remarkable. Therefore, the curvature of the generated curved surface becomes large.

[0027]

Then, the u_o is calculated to minimize the energy function E(u). If $u=u_o$, minimum E(u) can be obtained,

$\nabla E(u_o) = \nabla S(u_o) = 0$.

By expanding this, the primary simultaneous equation can be obtained. The unknown data is derived as a solution of the primary simultaneous equation. The curved surface can be generated by the derived unknown data. Where by modifying the value of γ desired filling can be achieved. By generating the curved surface used with only unknown data, and connecting the generated surface with the outline of the hole 90, then filling process is completed.

[0028]

In the embodiment described above, the parameter defining the curvature corresponding to one input item can be plural (for example, independent parameters are used for x axis direction and y axis direction). The represented member for use in modifying operation of the parameter is not limited in slider and thus a dial like

member can be used.

【0029】

【ADVANTAGEOUS EFFECT OF THE INVENTION】

According to the invention of claims 1-4, desired curved surface can be added on to the shape model by the simple and easy operation.

【BRIEF DESCRIPTION OF THE DEAWINGS】

【Fig. 1】

Fig. 1 is a block diagram showing a three-dimensional processing apparatus according to an embodiment of the present invention.

【Fig. 2】

Fig. 2 is a schematic diagram for illustrating a filling process.

【Fig. 3】

Fig. 3 is a diagram for explaining a first operation example.

【Fig. 4】

Fig. 4 is a diagram for explaining a second operation example.

【Fig. 5】

Fig. 5 is a diagram for illustrating a data processing for filling of a lacked portion.

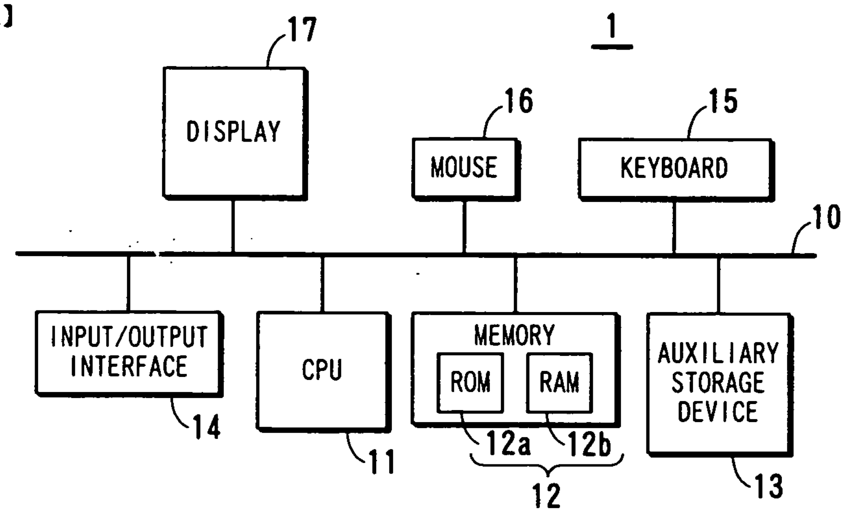
【EXPLANATION OF RFERENCES】

M	shape model
m1-m5	curved surface (curved surface model)
90	lacked portion (position to be corrected)
G1-G5	images
72	dialogue window (member)

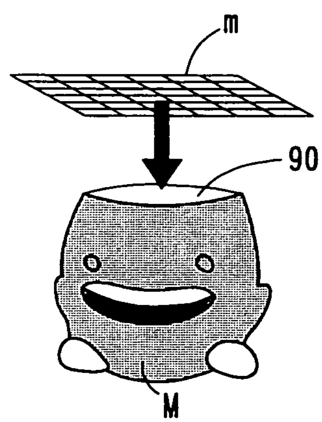
【PAPER NAME】 Abstract
【ABSTRACT】
【PROBLEM】 The primary object of the invention is to provide a method and system for adding a required curved surface applied on a portion of the shape model by a simply and easy input operation.
【MEANS TO SOLVE THE PROBLEM】 A method for correcting three-dimensional shape data by joining a surface to a part of a shape model is provided. The method includes a first step of generating curved surface models m1-5 each of which has an outline corresponding to a portion to be corrected of the shape model M, an entire curvature of the curved surface model being defined by a parameter corresponding to one input item, a second step of displaying images G1-5 showing a condition that each of the curved surface models m1-5 is positioned on the shape model M, and a third step of transforming the curved surface model responding to an operation of changing designation of a parameter value.
【SELECTED DRAWING】 Fig. 4

【PAPER NAME】 Drawings

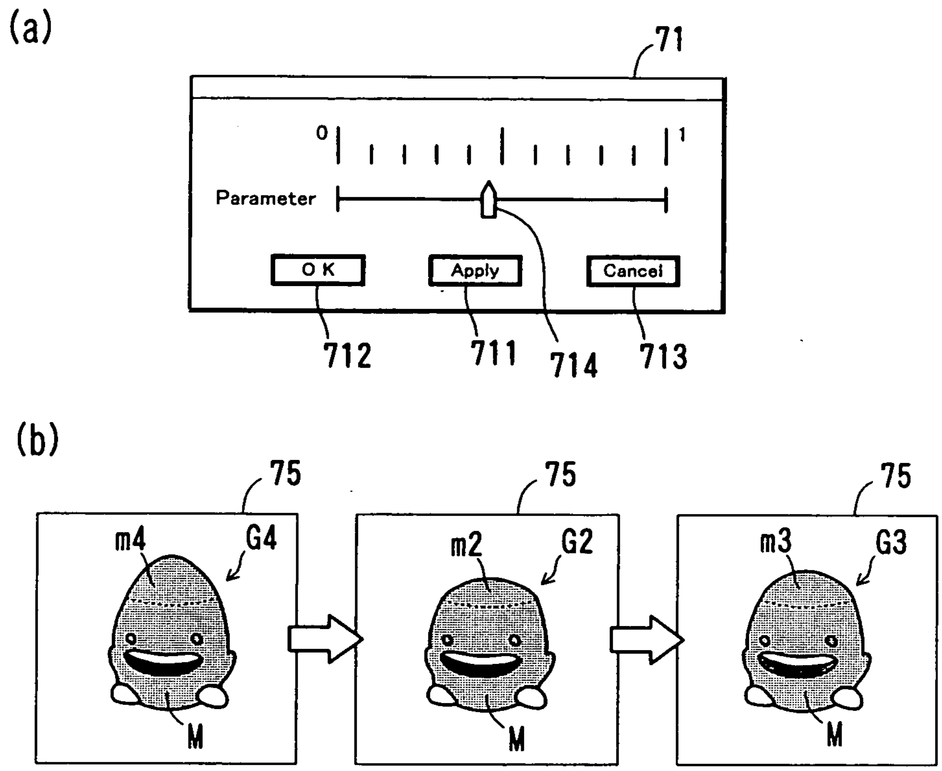
【FIG.1】



【FIG.2】

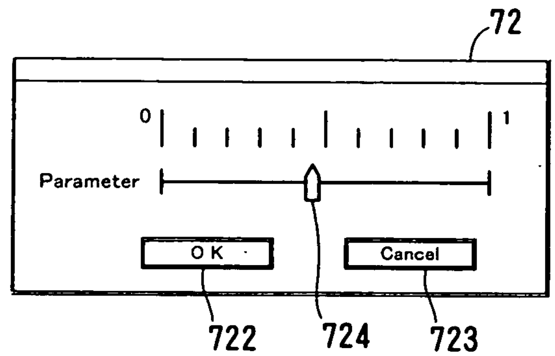


【FIG. 3】

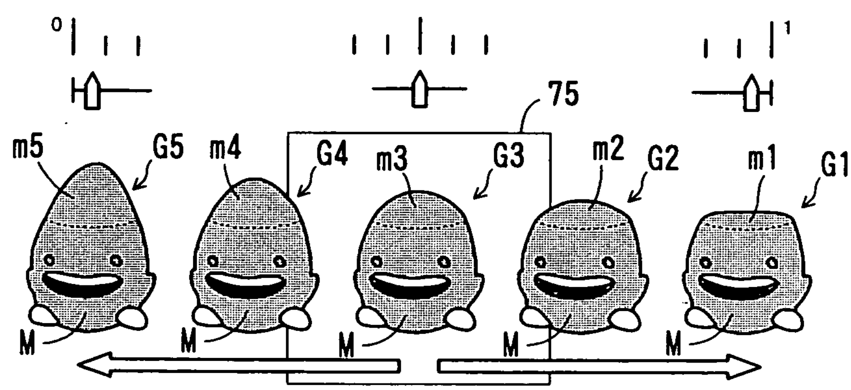

(a)
71
0
1
Parameter
O K
Apply
Cancel
712
711
714
713
(b)
75
m4
G4
M
75
m2
G2
M
75
m3
G3
M

【FIG. 4】

(a)

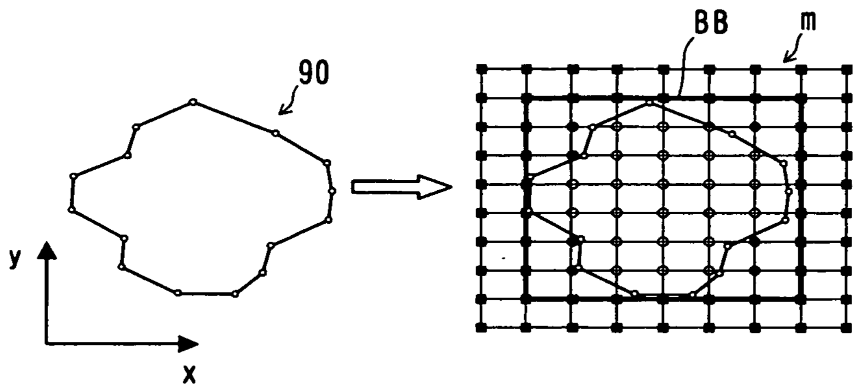

72
0
1
Parameter
O K
Cancel
722
724
723

(b)

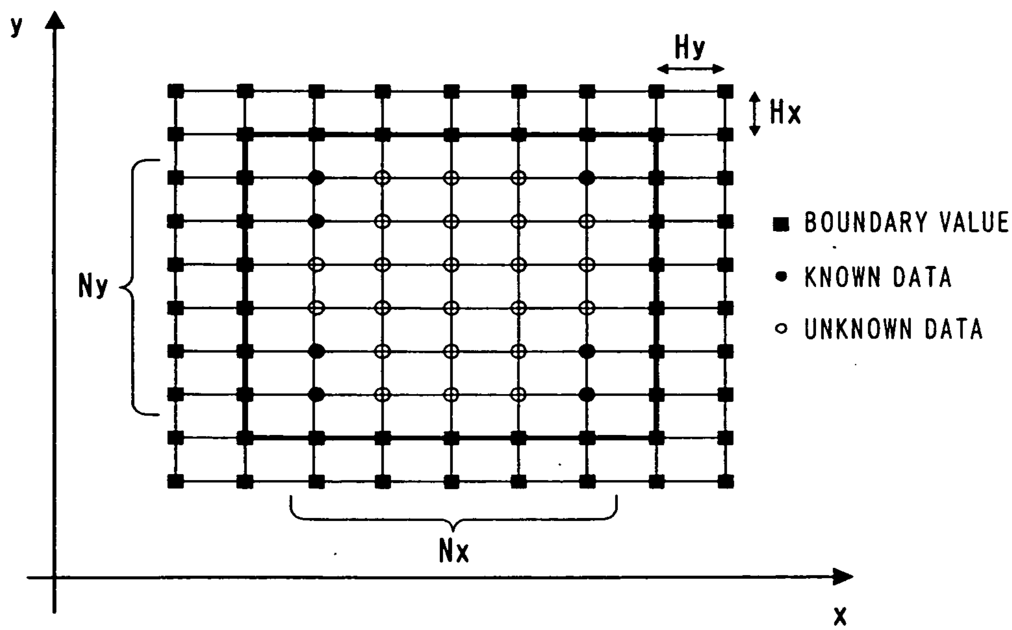

0
1
75
m5
G5
m4
G4
m3
G3
m2
G2
m1
G1
M
M
M
M
M

【FIG. 5】

(a)


90
BB
m
y
x

(b)


y
Hy
Hx
Ny
Nx
x
BOUNDARY VALUE
KNOWN DATA
UNKNOWN DATA